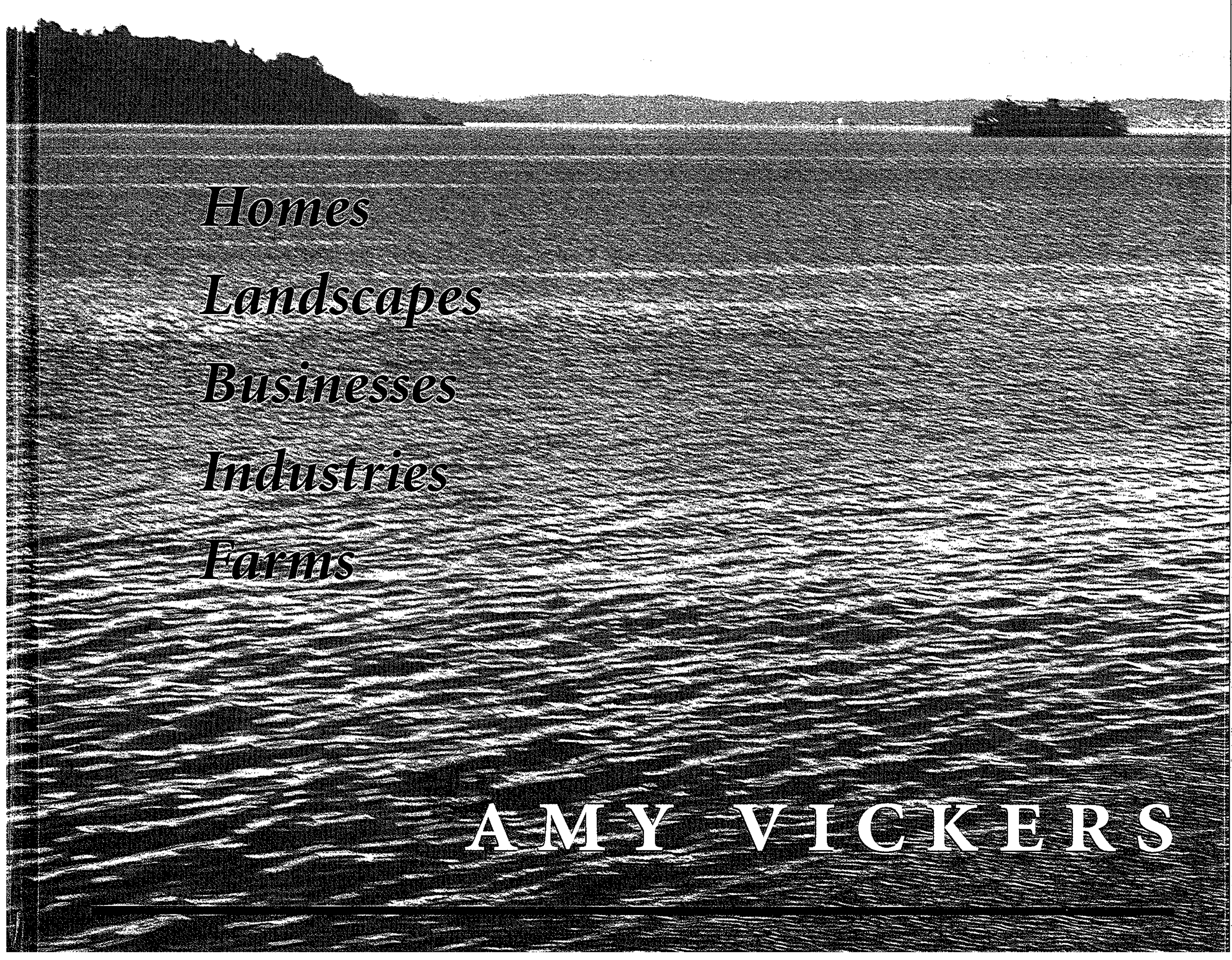
HANDBOOK OF

Water Use and Conservation



Homes

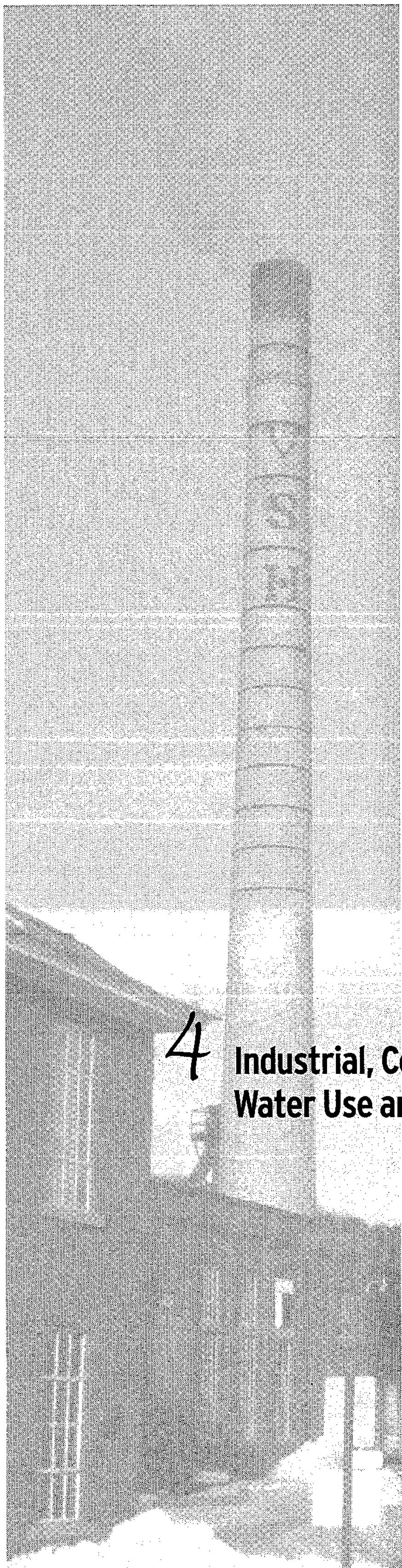
Landscapes

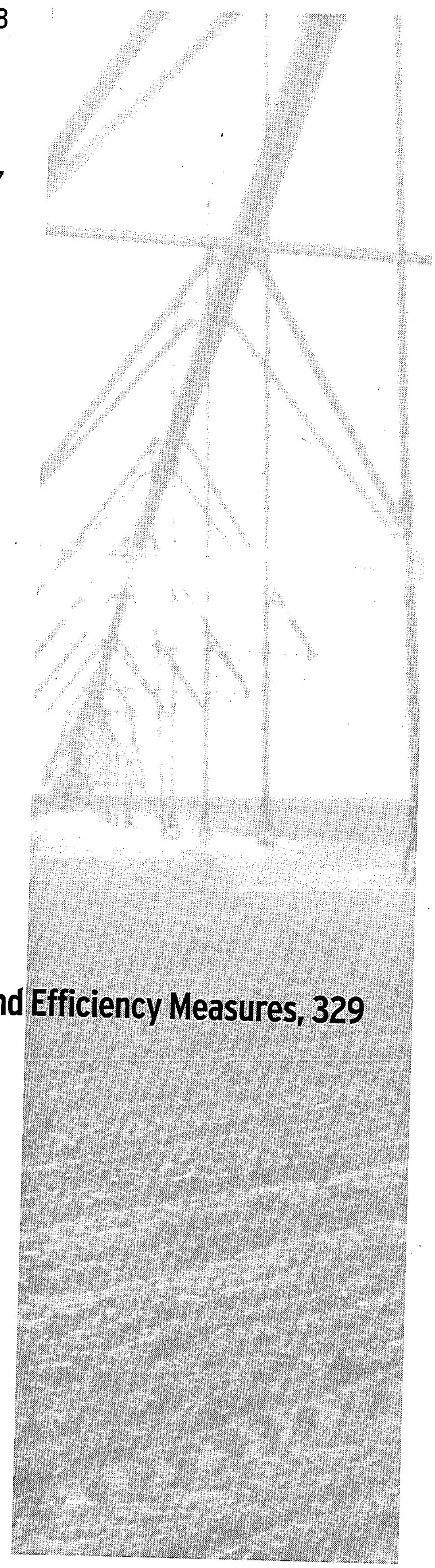
Businesses

Industries

Farms

AMY VICKERS





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two autoclaves, each using 2.0 gpm for every 10-minute sterilization cycle, were operated five times a day with full loads instead of eight times a day with partial loads, about 120 gpd would be saved. Implementation of this measure at a medical office that operates the machines an average of 260 day per year would save 31,200 gallons of water per year (gpy). With no cost involved for implementation, this measure, along with a combined water and sewer service rate of $4 per thousand gallons, would save about $125 a year and provide instant payback.

Types of Water Use at Hospitals and Health Care Facilities Follow a Pattern

Water use by hospitals and health care facilities varies widely because of differences in facility patient capacity, services, and operating procedures. Variability results from factors such as on-site or off-site rehabilitation facilities, laundry services, landscaping, and facility cooling and heating systems. Although overall water use from one facility to another cannot easily be compared, types of use appear to follow a trend. Typical water use in hospitals can be classified into about nine categories: 35% for domestic use (by plumbing fixtures and appliances), 15% for cooling, 15% for laundry, 10% for sterilizers, 7% for vacuum pumps, 5% each for x-ray processors, food preparation, and miscellaneous uses, and 3% for landscaping.[66] Miscellaneous uses include rehabilitation swimming pools, water treatment and softening equipment, and air control equipment.

4.3 PROCESS WATER USES

Process water in the commercial and industrial sectors is used primarily to clean products, to remove or transport ingredients, contaminants, or products, and to control pollution or dispose of waste. Some of the more common uses of process water are for washing and rinsing, materials transfer, photographic film and x-ray processing, and pulp, paper, and packaging production. The quantities of water used for processing vary according to use and are usually site-specific.

Audit Information to Be Collected on Process Water

Information that should be collected about process-water uses during an ICI facility water audit includes:

- Review facility production rates and determine or estimate total water use for each process-water end use by creating a diagram showing water going into the site and wastewater going out; include all water that is recycled and reused.
- Determine the hours of operation and actual pump and flow characteristics for all process-water uses.
- Review data from facility water and sewer meters and talk to operations staff about the source(s) of water used, including public and private (on-site wells, ponds) sources as well as water derived from reuse and recycling processes.
- Identify the water quality requirements (e.g., untreated, reclaimed, potable, or ultrapure) of each water-using process.
- Check the amount of wastewater being discharged and review records that might identify its chemical constituents.
- Identify all health, safety, operational, regulatory, administrative, and other requirements or policies that apply to the site.

Conservation Policies and Regulations Related to Process Water

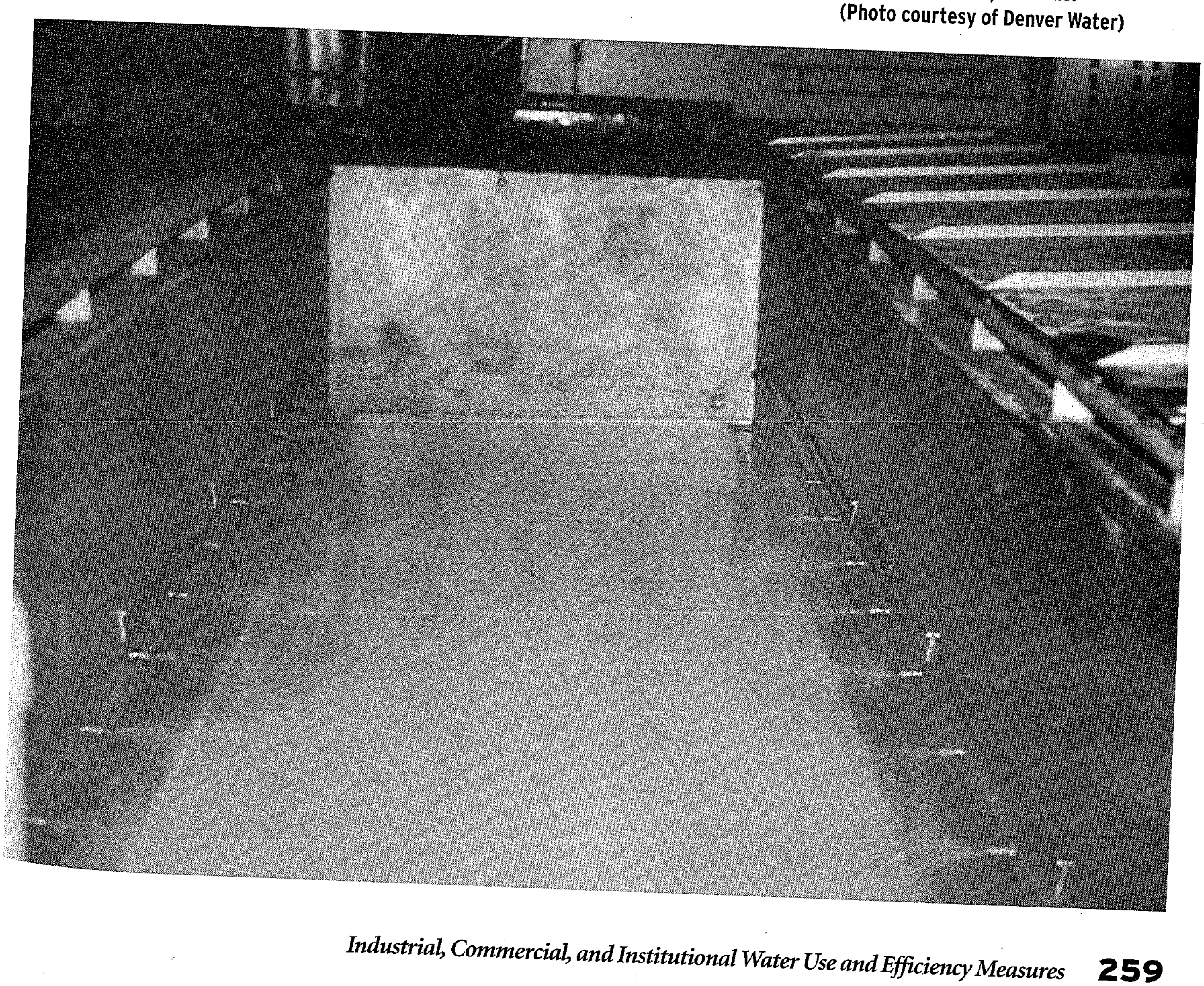
- ***Requirements for water audits and efficiency measures at federal facilities.*** Federal laws and executive orders pertaining to water and energy conservation requirements are described under Section 4.2, "Cleaning and Sanitation."

4.3.1 Process Washing and Rinsing

Process washing and rinsing are water-intensive but necessary operations for a number of industries, particularly metal finishing shops and computer chip manufacturers. Water in a rinse bath, as shown in Figure 4.11, may be static, constantly flowing, or flowing in a countercurrent pattern. A static rinse bath is a tank filled with water and process chemicals. Products are dipped in the bath to remove contaminants and extraneous material, and the tank is regularly drained and refilled with freshwater for processes that require multiple rinses. Constant-overflow rinse baths, or running rinses, have water continuously flowing into the tank and an overflow connected to a discharge drain. Some constant-flow rinse baths are operated continually even though they are used only occasionally. Each rinse bath is usually an essential part of the manufacturing method and may involve delicate processes and chemical interactions. Thus, rinse baths should be carefully evaluated before water-efficiency modifications are made.[62, 67–69]

In the electronics and metal finishing industries, product components are often rinsed with ultrapure deionized water to remove the chemical residue accumulated during manufacture. Deionized water is produced from public or private water sources using treatment techniques such as filtration, ion exchange, reverse osmosis, carbon adsorption, or ultraviolet radiation. Because deionized water is relatively expensive to produce, reducing its use will also cut down on the cost of its production.[69] In some cases, deionized water can be treated and reused.[70]

Figure 4.11 Process washing and rinsing are often extremely water-intensive operations. (Photo courtesy of Denver Water)



Case Study ***Improved Manufacture of Printed Circuit Boards Reduces Water Use.*** The Merix Corporation's Forest Grove facility in Portland, Oregon, manufactures printed circuit boards (PCBs) for computers, a process that requires considerable water and energy. The Forest Grove plant implemented a number of conservation measures that reduced its water use by 12.6 mgy, saving $190,000 annually. Measures included adjusting the placement, frequency, and flow of process nozzles, valves, and floats used to wash PCBs after stripping and etching. The facility expanded its closed-loop chilled water system to additional process lines, began reusing filtered wastewater to rinse the sludge press, and installed a secondary reverse osmosis treatment system that is saving about 21,600 gallons of water a week. In addition, excess water around the building's foundation is now pumped and treated for reuse instead of being discharged to the sewer line, and energy-saving lighting, electrical switching, and programmable panels have been installed. Merix has also implemented similar measures at its Loveland, Colorado, site.[71]

Water-Efficiency Measures for Process Washing and Rinsing

Water-efficiency measures that may be applicable to industrial process washing and rinsing operations include:[11, 62, 67–69, 72–74]

- Identify all water-using processes and determine if less water could be used through process optimization, water reuse, more efficient technologies, and switching to alternative water sources. Apply water-efficiency technologies or modifications that are specifically geared toward a particular facility and process.
- Identify the most appropriate cleaning and rinsing process required. Potential options include switching to smaller tanks and sinks, converting from continuous-flow to intermittent-flow systems, using batch processing for equipment that processes items individually, and using measured amounts of water rather than continuous rinsing and cleaning streams whenever possible.
- Install in-flow meters, control valves, and sensors (e.g., electric-eye or level-float sensors) on equipment that uses freshwater to stop flows when a rinsing, washing, or filling process is completed; adjust flow rates to the minimum amount required. Use instruments that measure conductivity or total dissolved solids to monitor water quality and to control the quantity of water needed for rinses, electrically operated flows, and rinse-water feed valves.
- Install automatic timer-controlled shutoff valves for rinse flows wherever feasible, although in some cases manually operated valves may be preferable to automatic controls that allow unneeded flows.
- Use automatic washers that continuously recirculate wash and rinse water for items such as reusable containers.
- Use sequential rinsing when spent water from one process is reused as rinse water for another compatible process, e.g., using the rinse water from an acid bath for a caustic bath rinse.
- Treat rinse water from plating and metal finishing operations whenever feasible to recover metals and chemicals (for return to the plating bath) and rinse water (for return to the rinse system). Consider membrane systems and evapo-

rator/condenser systems as options to separate plating solutions and rinse water.

- Treat and reuse water from plating and metal finishing processes for certain cold water rinses. Improve the quality of the rinse water by reducing drag-out (the process solution separated from the plating bath by the product) through the use of air knives. Allow drag-out to drain into the plating tank sufficiently before the work is moved to the rinse tanks. Use of wetting agents in the plating bath can reduce drag-out by half because it reduces surface tension.
- For multitank operations, one option may be to use the first rinse tank as a static tank instead of a continuous-overflow tank in order to retain most of the drag-out in the first tank. This method can reduce the amount of water needed for additional rinses and for tank refilling. Another option for multitank operations may be to use countercurrent flow rinsing, a multitank rinse procedure in which water flows from tank to tank in the opposite direction from the process sequence. This protocol leaves the final tank with the freshest water and thus the cleanest rinse, allowing the preceding tanks to use less water from the subsequent tank(s). In some cases, using two countercurrent tanks instead of a single rinse tank has reduced water use by as much as 50%. Additional tanks, piping, and floor space may be required for setting up a counterflow system.
- Alternative rinse operations to improve the water-use efficiency, if compatible with the process, can include replacing rinse baths with a spray rinsing system that reuses spent rinse water and provides other water recovery processes.
- Use appropriate nozzles to direct rinse and cleaning sprays accurately. Spray rinses may be most effective with items that are flat, have small holes, or are cup-shaped.
- Avoid or minimize the use of water softening, reverse osmosis, and deionized water unless these processes are critical because they require additional backwash water, which is less reusable for other nonpotable needs. The amount of water required for reverse osmosis can be reduced by eliminating continuous rinses whenever feasible. Recycling deionized rinse water requires careful control of contaminated wastewater to avoid component failure, particularly in the electronics industry; treatment methods include many of the processes used to produce deionized water. Because the initial volumes of water in a rinse bath are likely to have the highest concentrations of contaminants, recycling only the less contaminated rinse water used later in the process may make more sense. Maintain the quality of deionized water by optimizing its use, eliminating some plenum flushes, and converting from continuous-flow to intermittent-flow systems.
- Reuse or recycle rinse water to the next wash whenever possible. Treatment options for wash water, if necessary, include dissolved air flotation and filtration.
- Water used for heat transfer purposes, such as cooling and heating water that is not chemically altered, can be pumped into holding tanks and used for another process.
- Avoid unnecessary dilution; use the maximum allowable contaminant concentrations in rinse tanks.
- Reduce rinse water in the solvent-degreasing process with tamper-proof conductivity meters to control make-up water for rinse tanks.

The Earth has music for those who listen."

—Shakespeare

- Recover, treat, and reuse filter backwash water.
- Install splashguards and drip trays. Install drain boards between process and rinse tanks to reroute drag-out back to the process tank.
- Repair leaks around process equipment.
- Reduce or eliminate trickle flows that continue to run after processing operations are finished.
- Extend the life of baths by inspecting all parts prior to plating; parts should be clean, dry, and free of rust and mill scale to minimize contamination. Wipe or prewash dirty parts using old solvent.
- Schedule wet process production so rinses occur for fewer hours during the day.
- Install pressure reducers if high-pressure incoming supply water is not needed. Low-pressure portable pumps may be an option for wash stations to reduce the total amount of water discharged.

Water Savings, Benefits, and Costs From Process Washing

A number of studies have investigated the water conservation opportunities and results achieved by commercial and industrial process washing and rinsing operations, particularly in the electroplating and electronic industries. For example, a study of water conservation measures implemented by ten electronics manufacturers in the Silicon Valley region of California identified significant water and cost savings achieved through water-use monitoring, recycling and reuse, equipment modification, improved landscape irrigation, and employee education. The companies involved in the study develop, test, manufacture, and market semiconductor chips, integrated circuits, and other electronic products. The amount of water saved per company ranged from 2 to 365 million gallons annually, and water use was typically reduced by 20 to 40%. Annual cost savings ranged from $28,000 to $153,000; paybacks on investments were typically less than one year.[69, 75]

Case Study ***Chip Manufacturer Saves Water With Process Innovations and Reverse Osmosis.*** Intel Corporation's microchip manufacturing facility in Rio Rancho, New Mexico, outside of Albuquerque is using about 4 mgd since implementing various water-efficiency innovations, far less than the 10 mgd originally projected. Furthermore, between 1995 and 1999, Intel's reductions in water use corresponded to a 70% increase in chip productivity. The water savings were achieved through installation of a high-recovery reverse osmosis system, improved chip washing and rinsing techniques, and water-efficient landscaping. Considerable amounts of ultrapure water are required to manufacture the computer wafers (chips) that are the brains of computers, cell phones, and other portable electronic devices. Intel's reverse osmosis system can suspend large amounts of silica in the water used in wafer production, thereby reducing the amount of purified water required. A pilot study of the system achieved an 85% recovery rate that yielded 1.0 gallon of purified water for every 1.2 gallons put through the system. Intel also saves approximately 757,000 gpd by reusing this water once it has gone through the manufacturing process for cooling tower make-up, exhaust scrubbers, and landscape irrigation. When a fluid-dynamics computer model of water used in Intel's wafer processing tanks showed that 50% of the flow was not rinsing chips, the company had a new wet bench designed, changing the shape and volume of the tank to optimize the amount of water used for rinsing. The redesigned wet bench not only saved water but also reduced the amount of chemicals and energy needed in process tanks. Intel now uses this new design at its other facilities worldwide. The Rio Rancho fabrication facility's 31 acres of grounds were upgraded with Xeriscape designs and plants and more efficient irrigation systems. These improvements reduced outdoor water use by about 60%.[76]

Case Study ***Air Scrubbers Use Seawater Instead of Freshwater.*** The Monsanto Company's NutraSweet Kelco plant in San Diego produces algin products used to stabilize, thicken, and suspend foods, pharmaceuticals, personal care products, paper and textiles, paints and coatings, oil field drilling fluids, and cement materials. As a by-product of algin production, volatile organic compounds (VOCs) are produced, and water-using packed-bed air scrubbers are used to control VOC emissions. Before implementation of water-efficiency measures, the air scrubbers used large quantities of freshwater. An engineering evaluation of the scrubbers led to major design changes allowing the use of salt water, an abundant water source in San Diego. The conversion was accomplished by installing high-quality corrosion-resistant copper/nickel alloy pipe to transfer seawater from the bay to the four scrubber units. Additionally, special strainers were included in the new lines to minimize fouling of the scrubbers by the corrosive saltwater. As a result of these measures, the plant's annual freshwater use declined by 150 mgy by the end of 1995; total water use declined by 20%, and reduced water and sewer costs saved more than $1 million.[77]

Case Study ***Metal Finishing and Process Industries Conserve Rinse Water.*** Two case studies of metal finishers in San Jose, California, illustrate the types of conservation measures and savings this type of industrial customer can achieve. Hi-Density Disc, a manufacturer of large magnetic memory discs for mainframe computers, began reusing its rinse water and implemented other process changes such as installing a new tank, piping, and a cartridge filter to reduce water waste. In addition, it instituted an aggressive training and monitoring program to ensure that its employees followed water-efficiency principles and procedures. Annual water savings from these efficiency measures totaled 2.3 million gallons, a 29% reduction from previous use. Annual cost savings were $200,000, and the payback period on the investment was less than one month. One adverse effect of the conservation measures for this company, however, was an increase in wastewater discharge violations because effluent contaminant concentrations increased. Another metal finisher, Dyna-Craft, installed air knives in its rinsing machinery to reduce the amount of rinse water needed. Dyna-Craft also installed flow restrictors in its deionized water rinse. Annual water savings from these measures totaled 13 million gallons, a 25% reduction from previous use. Annual cost savings were $129,000 a year, and the payback period on the company's water-efficiency investments was two months.[69, 75]

"A good example is the best sermon."

—Benjamin Franklin

4.3.2 Materials Transfer

Water is used to transfer materials (e.g., edible produce but not computer chips) for such processes as rinsing, washing, and ingredient or product transport, as well as for pollution control and waste disposal. For example, a *fluming* operation transports fruits or vegetables from delivery trucks to processing lines. After a truck unloads large bins of produce onto platforms, water is released into the bins to transport the produce through a gate into channels that lead to sorting equipment.[69]

Water-Efficiency Measures for Materials Transfer

Water-efficiency measures that may be applicable to materials transfer include:[69, 76]

- Flume water may be reused through bins and channels, often without treatment.
- Lower the depth of water in bins and channels to reduce volumes.
- Use intermittent discharges of water for product transport instead of continuous flows.
- Filter or recycle process water for other purposes that don't require potable water.

Water Savings, Benefits, and Costs From Materials Transfer

Case Study *Chili Pepper Plant Removes Peels With Recycled Water.* Border Foods in New Mexico, one of the largest green chili and jalapeno pepper producers in the world, roasts and prepares for shipping about 1 million pounds of peppers a day. Between 1992 and 1995, Border Foods achieved water savings of 27% per pound of peppers prepared, dropping from 0.7 gallons of water per pound to 0.5 gallons per pound. The company accomplished these savings by straining out pepper peelings from process water and chlorinating the water for reuse in (nonfood contact) peel-removal flumes. Border Foods also recycles the 47 million gallons of wastewater it produces annually, using it to meet all the irrigation requirements of 100 acres of alfalfa and grass farms. (Total water use rose after 1995 because jalapeno pepper production increased by 300% and the peppers are canned in brine water).[76]

Case Study *Packing Company Uses Recycled Water for Product Fluming.* The Gangi Bros. Packing Company, a tomato processing and canning plant in Santa Clara, California, implemented water-efficiency measures in its fluming process for transporting tomatoes by replacing freshwater with previously used (but chlorinated) process water. At the company's fluming operation, trucks unload tomatoes in large bins (about 350 cubic feet in size) onto cannery platforms. At the platforms, water is released into the bins to carry the tomatoes to sorting equipment. Water for the fluming process is recirculated by means of special valves in the discharge bins and flume dump system.[75]

Case Study *Canadian Meat-Processing Plant to Reduce Water Use by 15%.* The meat-processing industry requires significant volumes of water for processing, refrigeration, and cleanup operations. The Gainers meat-processing facility in Edmonton, Alberta, processes and packages raw and smoked meat products. An energy and water audit of the facility identified five conservation measures estimated to achieve annual water savings of 211,200 cubic meters, about 15% of total water use. The water-efficiency measures included installing low-volume, fine-mist sprayers to wash and cool products and racks; installing high-pressure spray guns and nozzles; installing low-volume showerheads; and replacing or retrofitting washroom toilets, urinals, and faucets with new fixtures or related devices. The audit also recommended drilling a well to supply water for stock watering and summer cooling, an action that does not optimize water-use efficiency but saves money. Annual water and sewer cost savings from the efficiency measures were projected to be more than Can$250,000, with an estimated payback period of about eight months.[78]

4.3.3 Photographic Film and X-Ray Processing

Film processors are used in photographic film laboratories operated by commercial establishments, law enforcement agencies, schools, and other facilities, as well as for x-ray film development in hospitals, medical and dental offices, and other types of health care facilities.

Most large photo and x-ray processing operations use automatic film developing equipment, whereas smaller systems are often operated manually. Newer automatic machines are more efficient than older ones and produce less silver to be discharged into wastewater. Automatic film processors typically use a constant stream of water for a series of chemical reactions to develop, fix, harden, wash, and bleach film. Most of the water is used in the wash and rinse cycles, although the amount varies with the type of film or the particular process required for development. Film and x-ray processing machines use water at average flow rates of 2 to 4 gpm. An efficient photo processing system used at hospital and health care facilities can average 2.0 gpm or less, although some systems may be operated at higher flow rates. Although x-ray processors can be equipped with automatic shutoff (standby) switches to reduce or stop the flow of water when film is not being processed, some machines may not turn off as intended and may continue to draw water even while not processing film.[65, 79, 80]

Water-Efficiency Measures for Photographic Film and X-Ray Processing

Water-efficiency measures that may be applicable at photographic film and x-ray processing facilities include:[79–81]

- Upgrade equipment to newer, water-efficient models.
- Adjust the film processor's flow rate to the minimum required; this may require installation of a control valve in the water line supplying each unit. (Flow requirements may vary by machine, even among the same models produced by the same manufacturer.) Install a simple flow meter in the supply piping, and post a list of minimum acceptable flow rates near the processor as a guide for employees who operate it.
- Automatic water shutoffs with solenoid valves can be installed on some equipment to stop the flow of rinse and cooling water when the unit is not in use.

The German physicist Wilhelm Conrad Röntgen discovered X rays in 1895 by accident while studying cathode rays. The contrast between body parts in medical x-ray photographs is produced by the different scattering and absorption of X rays by bones and tissues.
—Encyclopædia Britannica

Regularly check machines that are already equipped with such valves to make sure that the valve—and the developer—are turning off properly.
- Install pressure-reducing devices on water lines supplying equipment that does not need high pressure.
- If the unit is equipped with a squeegee, using the squeegee can reduce chemical carryover by as much as 95% and can lower the amount of water required in the wash cycle.
- Recycle rinse-bath effluent as make-up for the developer/fixer solution.

The main source of pulp and paper is wood. Wood is debarked, chipped, and then processed into pulp. The pulp is then washed, screened, thickened by the removal of most water, and bleached. Paper manufacture involves beating the pulp, loading, introducing various additives, refining, and running the pulp into a paper machine.

Water Savings, Benefits, and Costs from X-Ray Processing

An example of water savings that might be achieved with an x-ray processor in a medical office would be to reduce the flow of a continuously flowing unit from 4.0 gpm to 2.0 gpm (assuming such a measure is within acceptable operating procedures for the unit and film quality does not diminish) by adjusting the inlet valve (or installing a flow meter and adjustable valve) on the water line supplying the processor. For units that operate 12 hours a day, 260 days a year, estimated water savings would be approximately 374,400 gallons of water a year for each machine with such an adjustment. The flow meter and adjustable valve, if necessary, would cost about $175. Factoring in a combined cost of water and sewer service of $4 per thousand gallons, this measure would save about $1,500 a year in utility costs, generating an instant payback of about one month.

4.3.4 Pulp, Paper, and Packaging Production

The pulp and paper industry is one of the largest water-using industries in the United States. Factories have been estimated to use 15,000 to 60,000 gallons of water per ton of bleached pulp. Because of the intensity of water use in this industry, paper and packaging manufacturers who institute efficiency measures may have a competitive advantage over nonconserving facilities.[82]

Pulping, a common process in the paper industry, involves slurrying water and paper fibers to form a mixture containing 2 to 5% solids. The slurry or pulp is then dewatered through a series of steps, first on a rolling screen and then on continuously moving belts, to be used as an intermediate paper product in subsequent processes at the facility.[69]

Water-Efficiency Measures for Pulp, Paper, and Packaging Production

Water-efficiency measures that may be applied to pulp, paper, and packaging production include:[69, 82, 83]

- Recycling is the most effective water-efficiency measure in the pulp and paper industry, particularly recycling effluent from pulp mills and paper-production machines. The water and fibers recovered from the dewatering process during pulping can often be reused in subsequent pulping operations with little or no treatment, although recycling process water for paper production is more complicated. One of the challenges in using recycled water for paper production is the effect of "white," or process-contaminated, water on product quality and processing. The higher the quality of paper, the higher quality

process water required. Thus, using reclaimed water to produce high-quality paper and packaging requires that the water be pretreated extensively to achieve an acceptable chemical balance and to reduce the concentrations of corrosive agents and scale-forming suspended solids.
- Other water-efficiency measures that may be effective in the paper and packaging industry are use of reclaimed water, water blending, partitioning of process or cooling water, and advanced treatment technologies.

Water Savings, Benefits and Costs From Paper Production

Case Study *California Paperboard Corporation Reduces Water Use by 72%.* The California Paperboard Corporation (CPC) in Santa Clara, California, recycles paper and cardboard into paperboard and corrugated medium at a production rate of 240 tons per day, employing 100 to 125 employees on three shifts. Recycling and reuse of process water and installation of a new clarifier to recycle effluent for use in processes that require high-quality water resulted in overall water savings of 1.3 mgd, representing a 72% reduction in water use. Conservation measures, implemented over a period of many years, had saved CPC an estimated $767,100 per year in water and recycling costs by 1990. The key steps CPC used to identify and implement water-efficiency measures were: (1) identify major water uses, (2) evaluate minimum water quality and quantity needs for processes, (3) evaluate the degradation of water quality that results from each process, and (4) evaluate the feasibility of recycling process effluent for use in the same or another process with little or no treatment.[69]

4.4 COMMERCIAL KITCHENS AND RESTAURANTS

Commercial and institutional kitchens use water primarily for food and drink preparation, dishwashing, ice machines, ice cream and frozen yogurt machines, garbage disposers, and scrapping troughs. These kitchens also use water for additional washing and sanitation activities (including laundry), plumbing fixtures in restrooms, cooling and heating systems, and landscape irrigation; often some water is lost through leaks. Commercial and institutional kitchens are typically found in restaurants, cafeterias, hospitals, hotels, office buildings, large commercial establishments, and educational and correctional institutions.[84–88]

Audit Information to Be Collected on Kitchens and Restaurants

Information that should be collected about kitchens and restaurants during an ICI water audit includes:

- Number and type of water-using appliances or pieces of equipment (dishwashers, garbage disposers, ice makers, faucets, food scrapping troughs, and so on).
- Average number of loads per day completed by each water-using appliance and piece of equipment.
- Average number of meals served per day.